Leak Detection in Medium Density Polyethylene Pipeline using Ensemble Empirical Mode Decomposition Method

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ABSTRACT

A water resource is an important element in the contemporary society life. In global world water loss or water leaking can vary between 10% to 40% of total water volume produced. A traditional method such as visual inspection can be operates but that method required a long time. The objectives of the research to identify the occurrence of leaks and know its exact location in the pipeline by using specific method which are acoustic leak detection method and transient method. An EEMD method will be applied as the analysis method to collect and analyses the data. Based on the experimental results that the EEMD analysis predict satisfactorily the location in MDPE pipeline as it can detect and locate the leak up to error of 4.09% and 0.61%. The EEMD method had the best perform and already produce an acceptable result.

Keywords Leak Detection, MDPE, EEMD Method, Signal Processing
Paper type Research paper

INTRODUCTION

A water resource is an important element in the contemporary society life now. From the end of the rural area, right down to the big city, each individual need clean water supply with best guaranteed quality. Currently, over 1.4 billion people live near water resources where the use of water already exceeds minimum recharge level resulting depletion of ground water [18]. Pipe leaking can be happened in many forms such as burst, hole and cracks. In global world water loss or water leaking can vary between 10% to 40% of total water volume produced, which can be great economic importance [1]. History proves that every generation of human were always trying to produce the best and efficient water supply system. As time goes, every generation tries to improve the previous system and existing. Many intellectuals and engineers were trying to design and improve an efficient water and fluids distribution system.

The design must consider many aspects so that the system not suffer from leaks and rupture that may result huge loss of water of fluids and of course raising the cost of transferring. Nowadays, quick leakage detection and reduction is a high-profile activity and seen by many waters distribution company and the regulators as a priority, not only in the economical perspective, but also to preserve environment and natural resource from any waste and pollution.

For leakage detection technique, there have two types which are external and internal based technique or otherwise known as hardware and software techniques [2]. External bases technique is a system that utilizes any field instrumentation to monitor and check around external pipeline parameters while the internal based technique is a system that monitors internal pipeline parameters.

The transient-based method used to rise the leak location sensitivity by simulating and reproducing transient in the pipeline so that leak effect can be spread out and captured [3]. In transient method, leakage can be detected typically via comparison of the pressure signal that captured by monitoring devices to the signal that would be observed if the system that did not have leak. The other way is where leakage can be detected is through its role in pressure relief. When the high pressure passes, leak will cause some attenuation in first transient signal by let some of fluid down with pressure escaped. In transient-based method, both types of waves propagation (dispersion and attenuation) are play important roles to detect leakage. Water hammer phenomenon also known as hydraulic transient usually occur at fast flow changes in pressurized water pipelines as shown in Figure 1 [4].

A traditional method such as visual inspection can be operates but that method required a long time. Through signal analysis, the leak can be detected and the location of the leaks can be located [5]. The history of signal analysis is starting by using Fourier transform techniques. But this method has its own limitations. It can only detect the leaks but cannot identify the location and the time when the leaks occurred. So, in order to obtain an accurate and complete data of the leak, many techniques of signal analysis have been developed such as Wavelet Transform [6]–[8], Cepstrum Analysis [9], [10], Empirical Mode Decomposition (EMD) [11], Ensemble Empirical Mode Decomposition (EEMD) [12], and many more. The objectives this research to identify the occurrence of leaks and know its exact location in the pipeline by using specific method which are acoustic leak detection method and transient method. An EEMD method will be applied as the analysis method to collect and analyses the data.

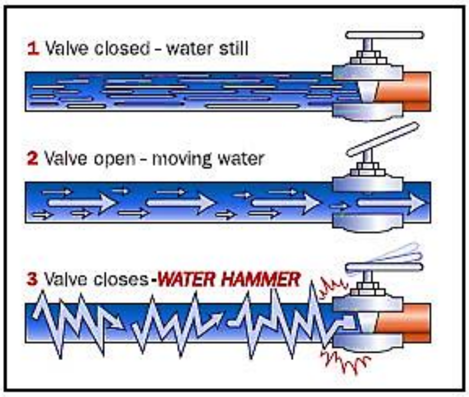

Fig. 1. Water hammer in pipeline [13]

METHOD

First of all is specifying the distances of pressure transducer with leak location at the pipeline. The length of pipelines was determined and for the experiment, two types of material for pipe was selected that is Medium Density Polyethylene (MDPE) pipe. For the experiment, pin point type of leaks will be used at the pipeline. There has some different dimension of diameter for both types of pipes to be assembled. In this experiment, there will be use different features use in pipeline system such as elbow 90 for bending and tee junction.

The experimental procedure, test rig will be form by sequences of pipe, certain features and analysis equipment. As for pipeline, the MDPE pipe is used for the experiment. The test rigs were connected to hydraulic bench which consist water tank and average power water pump. The experiment was designed by followed schematic diagram as in Figure 3.9, where involve U-shaped pipeline with features.

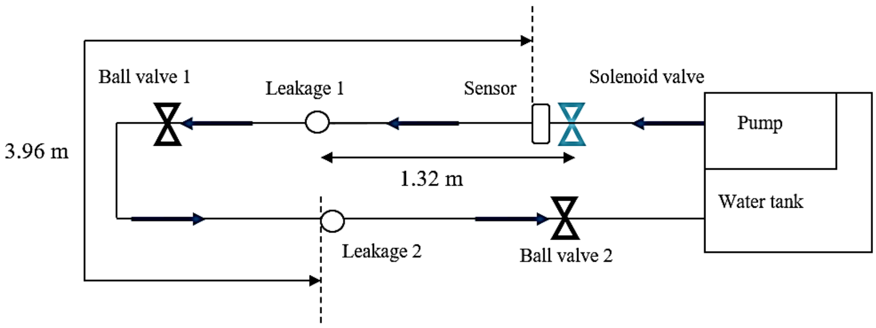

Fig. 2. Schematic diagram for MDPE pipeline leak detection

Fig. 3. Test rig for MDPE pipeline leak detection

The captured signal was transferred to data acquisition. For the study of MDPE pipeline, 1600 sample size and sampling rate at 1600 Hz was required. Other tools that been used was DASY lab software where strain value and transient graph was recorded. Basically, EEMD method contains four simple steps starting with the addition of white noise series to original targeted data. Next, proceed with data decomposition by add the white noise into intrinsic mode functions (IMF). By doing these two steps, the different white noise series can be adding each time and the process is repeating again and again. After obtain each data decomposition with different white noise, the final result can be observed at ensemble means of corresponds to IMF of the decomposition.

ENSEMBLE EMPIRICAL MODE DECOMPOSITION

The Ensemble empirical mode decomposition (EEMD) is an approach that consists of sifting an ensemble of white noise added signal data. This analysis method keeps the mean as the final result. The amplitude of white noise is required in this method to force the ensemble to bring out all possible solutions in the sifting process. After sifting, the signal will be scaled differently in intrinsic mode functions (IMF) dictated by dyadic filter banks. EEMD analysis is generally known as time space analysis method [14], [15]. EEMD principle is by added white noise, it will populate whole time frequency space uniformly with constituting components of different scales. The general equation that can be used in EEMD is:

$$x(t) = \sum_{j=1}^{n} c_j + r_n \tag{1}$$

where r_n is the residue data, n is number of IMF extracted, c_j is number of zero-crossing

The ensemble mean is effective result that can be obtained by using EEMD, where data are collected by separate observations, each of which contains different noise. To generalize this ensemble idea, noise is introduced to the single data set, x(t), as if separate observations were indeed being made as an analogue to a physical experiment that could be repeated many times. The added white noise is treated as the possible random noise that would be encountered in the measurement process. General equation for this idea is:

$$x_i(t) = x(t) + w_i(t) \tag{2}$$

where $x_i(t)$ is mixed data with noise, $w_i(t)$ is white noise, $x(t)$ is single set of the original data.

RESULTS AND DISCUSSION

The result and data were recorded by using data acquisition device in term of pressure or voltage versus time value. Each of data set have been analyzed in MATLAB software by using ensemble empirical mode decomposition. The analysis method is the continuation of previous empirical mode decomposition where the method applies ensemble of white noise in the decomposed data and signals. Each of decomposed data called intrinsic mode functions (IMF) and by decomposing the signals, leakage location can be determined by substitutes time value at leakage signal obtained in specific equation for leakage location.

Medium density polyethylene pipelines have lower speed of sound compare to galvanized iron pipelines. The value speed of sound or wave speed is depended on many criteria and aspect such as fluid density, elasticity modulus of pipe, bulk modulus, and thickness of pipe and elasticity of conduit in pipelines. As in experiment, there are many constraints and limitations while measuring wave signal in the MDPE pipelines. By using piezoelectric sensor, the result for both sample without leakage and leakage was analyzed.

By using piezoelectric sensor, signal wave in the MDPE pipelines was successfully captured at sample size and sampling rate 1600. Figure 4 shows the signal captured in MDPE pipeline without leakage within 15 seconds. The signal is decomposed into seven IMF with the final component indicating the residual of the signal. Transient of signal was stimulated by solenoid valve at zero seconds. The figure also shows transient signal waves that happen in time frame 15 seconds been decomposed by using ensemble empirical mode decomposition with addition of 0.2 amplitude of white noise and 100 ensembles, the decomposition removes unnecessary noise in the data set. From Figure 4, there is no sudden change in signal wave after been stimulate by solenoid valve at zero second. The data is decomposed at seven intrinsic mode function (IMF) and the result shows that the leakage is not present. The data in Figure 4 was determined as normal signal data without leakage in the MDPE pipelines and the data will be compared with other data to see if there are leakage are present.

Figure 5 shows the signal captured in MDPE pipeline with leakage within 15 seconds. The signal is decomposed into seven IMF with the final component indicating the residual of the signal. Transient of signal was stimulated by solenoid valve at zero seconds. From the signal data set, it shows an obvious signal transient at 4.63 seconds. The transient was unable to be recorded in signal wave data without leakage, so the data is assuming as a potential leakage that happen at 4.63 seconds. The figure also shows other transient signal waves that happen in time frame 15 seconds but after been decomposed by using ensemble empirical mode decomposition with addition of 0.2 amplitude of white noise and 100 ensembles, the signals were removed. The transient signal at 4.63 seconds still can be detected until at six IMF.

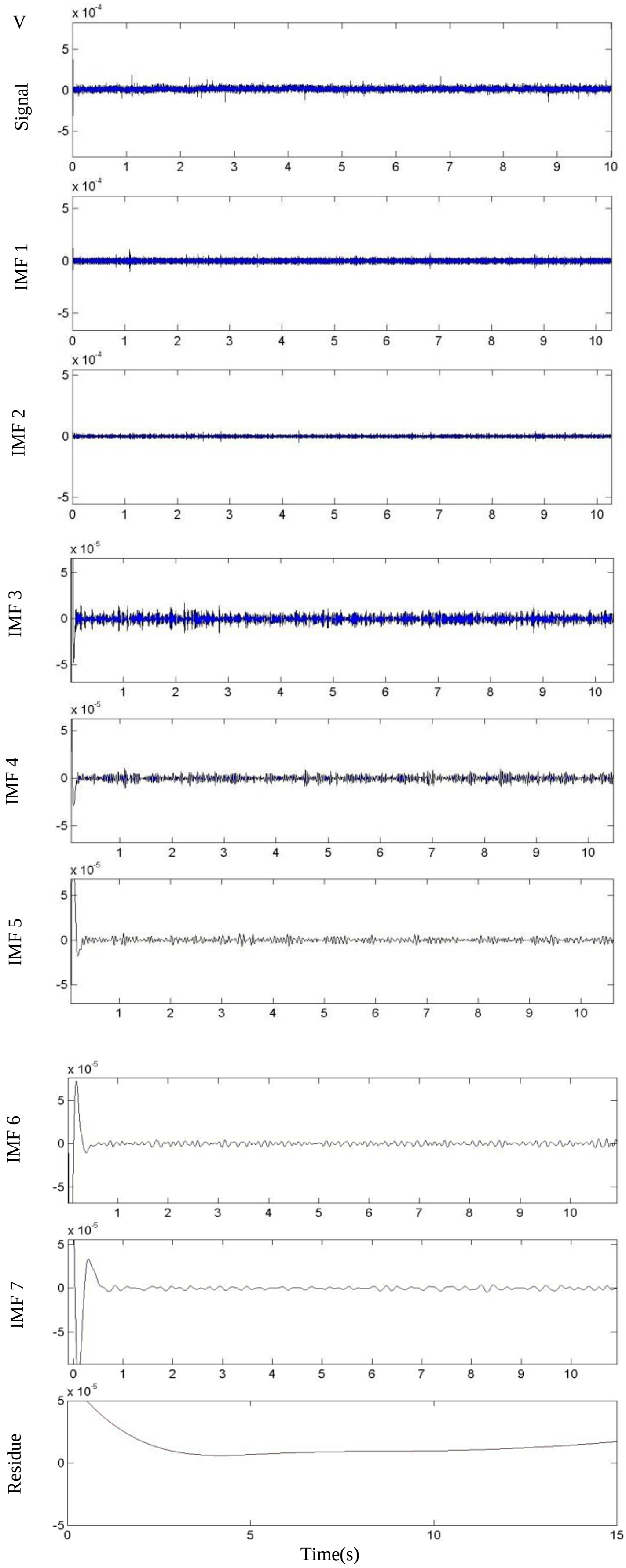

Fig. 4. The EEMD analysis graph without leakage for MDPE pipeline

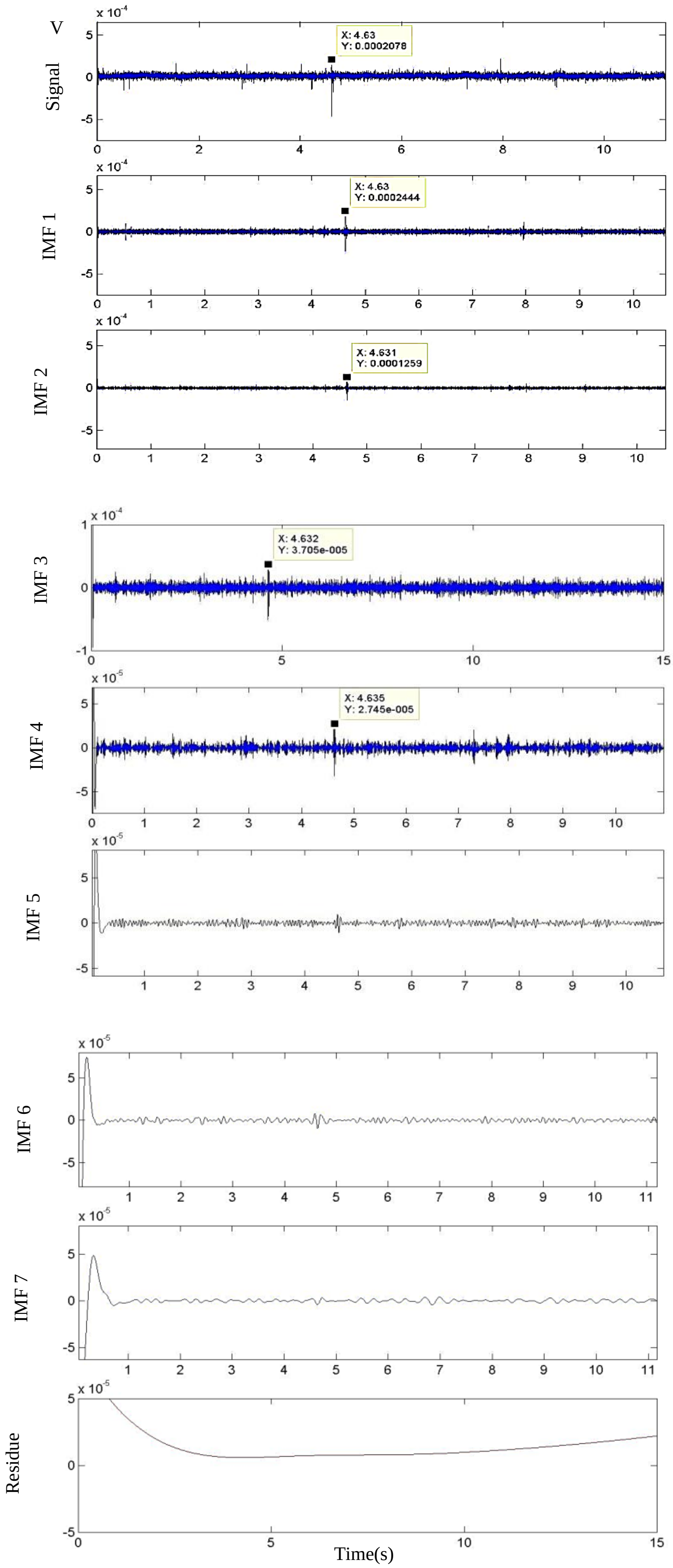

Fig. 5. The EEMD analysis graph with first leakage for MDPE pipeline

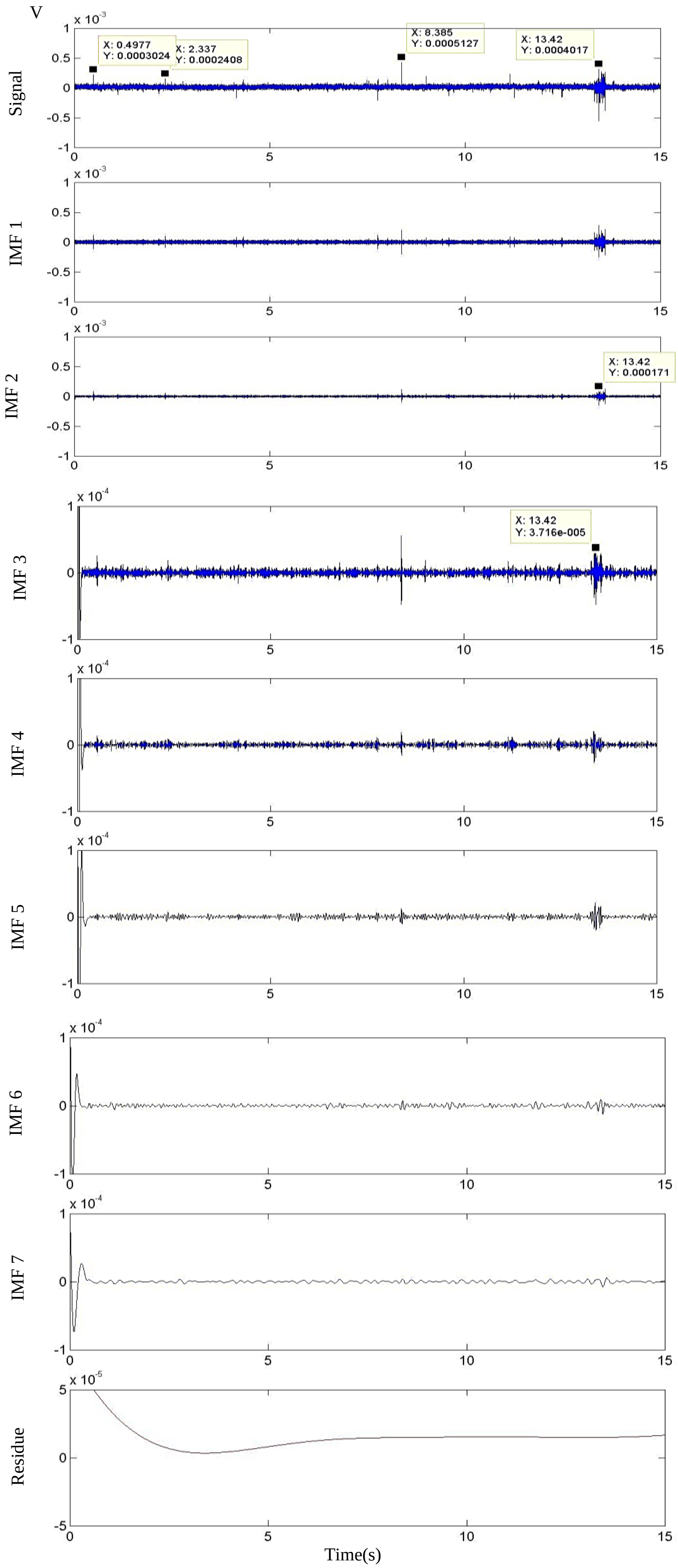

Fig. 6. The EEMD analysis graph with second leakage for MDPE pipeline

In MDPE pipeline, the propagation speed is 950 m/s and time change is 4.63. The equation needed to divide with 1600 because of the data was recorded in sample rate 1600 in one second. The result is 1.374 m which is nearly accurate to measured leakage distance that is 1.32 m. It can be concluded that the existed transient wave signal at 4.63 seconds is the first leakage in time frame 15 seconds and there only 4.09% of error occurred in the analysis and measurement. The error may cause by additional noise influenced by motor pump that was located not far away from the leakage, undetectable leakage at joint of figure and lag happens when the data was captured and recorded.

Figure 6 shows the signal captured in MDPE pipeline with leakage within 15 seconds. The signal is decomposed into seven IMF with the final component indicating the residual of the signal. Transient of signal was stimulated by solenoid valve at zero seconds. From the signal data set, it shows an obvious signal transient at 13.42 seconds. The transient was unable to be recorded in signal wave data without leakage, so the data is assuming as a potential leakage that happen at 13.42 seconds. The figure also shows other transient signal waves that happen in time frame 15 seconds but after been decomposed by using ensemble empirical mode decomposition with addition of 0.2 amplitude of white noise and 100 ensembles, the signals were removed. The transient signal at 13.42 seconds still can be detected until at fifth's IMF. The transient signal at 13.42 seconds was calculated into time related distance same as previous calculation for signal at Figure 4.4 and the result obtained is 3.984 m. The actual measured distance is 3.96 m and percentage error for the obtained result is about 0.61%.

Table 1 shows outcome of analyzed distance compared with measured distance for leakages at both types of pipelines. From the table, it shows tiny margin of error percentage for each leakage along the pipeline. Ensemble empirical mode decomposition analysis method had been performed on both types of MDPE and GI pipeline in order to identify leaks along the pipeline. Firstly, the signal been recorded at certain time frame with stimulated transient signal from solenoid valve at zero seconds. Next, the collected transient data was decomposed and filtered by ensemble empirical mode decomposition (EEMD). The features that were identified as a causing a reflection were element such as a leak, a corner and valve but leak only been analyzed because to analyzed any other features, a new experiment, calibration and data set of signals is needed to measure and determined their exact location.

TABLE I. SUMMARIZED RESULT

Pipelines	Features	Analysed distance (m)	Measured distance (m)	Error (%)
MDPE	Leak 1	1.37	1.32	4.09
	Leak 2	3.98	3.96	0.61

CONCLUSION

The transient analysis causes by water hammer phenomenon was used to find leakages location along the MDPE pipeline. Pressure transducer and piezoelectric sensor were used to measure changes in wave propagation hence deliver the data to be recorded by data acquisition device in form of signal data set. The signal data set is been analysed by using Ensemble Empirical Mode Decomposition (EEMD). The data obtained then was calculated in leakage detection equation influence by sample size of the signal was recorded. Based on the experimental results that the EEMD analysis predict satisfactorily the location in MDPE pipeline as it can detect and locate the leak up to error of 4.09% and 0.61%. The EEMD method had the best perform and already produce an acceptable result.

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